Nutrient Assessment Protocols for Wadeable Streams in Nevada

August 2007

Algae at East Fork Carson River between Highway 88 and Muller Lane, July 2004

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Introduction

The purpose of this document is to provide some general guidance on possible steps for determining the nutrient impairment status of wadeable streams in Nevada. These protocols will be useful in addressing a two key issues:

> **303(d) List:** Of the some 100 waterbody reaches listed in 2004 303(d) List, nearly 50% are shown to have exceedances of total phosphorus standards. However, NDEP is not confident in the appropriateness of the phosphorus standards throughout the state. It is hoped that these protocols will be useful in determining whether or not these listed waters are truly impaired. Appropriate next steps (additional monitoring, water quality standards revisions, TMDL development, targeted 319 projects, etc.) can then be determined. Before a large amount of resources are devoted to developing TMDLs and control strategies, it is advisable to evaluate the eutrophication status of 303(d) Listed waters using these protocols.
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> **Appropriate Nutrient Criteria:** As described in Nevada's Nutrient Criteria Strategy (NDEP, 2007), NDEP faces significant challenges in reviewing/revising existing nutrient criteria and establishing new criteria for new waters to be included in the regulations. Nutrient levels are believed to be a poor indicator of nutrient impairment. Rather parameters such as dissolved oxygen and algae density are much better measures of stream health as affected by nutrients. Assessments, such as described in this document, will increase the state's database on nutrients, algae levels and other factors. As a result, NDEP will be better equipped to move toward more appropriate nutrient criteria throughout Nevada.

This document is to be considered a living, changing report, which will be revised over time as NDEP obtains more data, tests these protocols, and gains more insight into Nevada's waters.

Background

Exceedances of total phosphorus standards are common in many of Nevada's streams. However in many cases, it is not known if the phosphorus levels are actually impacting the beneficial uses, e.g. aquatic life, recreation, etc. As discussed by TetraTech (2005), the use of nutrient concentrations alone are poor predictors of assessing eutrophication impacts. Also, Dodds et al. (2002) examined data from over 600 streams and found that nutrients concentrations accounted for less than half of the variance in the benthic algae biomass. They speculated that other factors, such as flow, light availability, channel conditions, grazing, were responsible for the remaining variability. In a detailed study of Colorado streams, Lewis, Jr. and McCutchan, Jr. (2005) found even less of a relationship between nutrient concentrations and benthic biomass, with DIN (dissolved inorganic nitrogen) accounting for only 15% of the variance. No statistically significant relationship was found between benthic biomass and other nitrogen and phosphorus species.

Given the problems of relying on nutrients concentrations to predict impairment, EPA Region IX RTAG (Regional Technical Advisory Group) has recommended the use of secondary indicators in determining impairment status (Tetra Tech 2006). Key indicators for streams include: 1) benthic algal biomass; 2) dissolved oxygen; and 3) pH (photosynthesis driven). It is believed that these three parameters are more direct indicators of stream use support/impairment status than N and P concentrations.

Of these three indicators, algae is the primary driver. While some algae is a necessary component of the ecosystem, excessive algae can impact the beneficial uses in a variety of ways. According to EPA (2000):

> *"Algae are either the direct or indirect cause of most problems related to excessive nutrient enrichment, e.g. algae are directly responsible for excessive, unsightly periphyton mats or surface plankton scums, and may cause high turbidity, and algae are indirectly responsible for diurnal changes in DO and pH"*

Secondary Indicator Thresholds

Algal Biomass: Table 1 presents a summary of various algal biomass limits that have been recommended by others for the protection of various uses. Maximum chlorophyll a densities range from 50 to 200 mg/m^2. Biggs (2000a) states that some of these values have been determined subjectively, and that more quantitative study is needed to define the public's perception of what might be "excess" algae for recreational and aesthetic uses. However, Biggs recommends biomass threshold levels for recreational/aesthetic uses that are similar to the other authors.

It appears that algae levels may impair other uses such as recreation before DO problems are experienced. According to EPA (2000), there are no apparent effects on DO, pH or benthic invertebrates at the 100 - 200 mg/m^2 (chl. A) level. For example, Truckee River data shows that biomass levels much higher than in Table 1 do not necessarily lead to DO problems. During June 2001, biomass levels at various transects between the TMWRF discharge and Derby Dam ranged from around 200 to over 15,000 mg/m^2, with the average for all transects about 2000 mg/m^2 (chl. A), yet no DO problems (<5 mg/l) were measured.

Unfortunately, there appears to be limited information on appropriate biomass thresholds needed to protect aquatic life uses. Nordin (2001) presented 100 mg/m^2 and stated that this "*criterion is designed primarily to protect fish habitat and changes in communities of organisms such as invertebrates which are important themselves or which may be important fish-food organisms*." Biggs (2000a) recommended 50 mg/m^2 for protection of benthic invertebrate diversity based upon macroinvertebrate and corresponding biomass data for New Zealand streams. His studies showed that EPT invertebrates (mayflies, stoneflies, caddisflies) populations decreased sharply where periphyton biomass exceeds 13 mg/m^2 (chl. A), with the relative abundance of midges, worms and snails increasing greatly above this level.

Due to its importance as an impairment indicator, rapid algae monitoring will be considered as an initial step in the proposed assessment protocols. However, it is important to recognize that algal biomass levels can be highly variable with time and space requiring monitoring of numerous site over extended time periods. As a result, algae monitoring can be quite expensive depending on the rigor of the approach. A variety of methodologies for characterizing algal biomass have been developed by others – ranging from the qualitative (the least rigorous consisting of photographs and visual estimates of biomass) to the quantitative (the most rigorous consisting of algal sampling and laboratory analyses). Appendix A provides a quick summary of some key protocols.

Table 1. Algal Biomass Limits/Guidelines

Maximum Chlorophyll a – mg chl/m^2		% Cover		Use	Source
Diatoms	**Filamentous Algae**	**Diatoms**	**Filamentous Algae**		
150 - 200				Based upon perceived impairment	Welch et al., 1989
100 - 150			20%	Based upon 19 enrichment cases and surveys	Welch et al., 1988; Horner, et al., 1983
100 - 200				Nuisance	Dodds et al., 1997
200				Eutrophy	Dodds et al., 1998
150					Watson and Gestring, 1996
n/a	120	60% of diatoms > 0.3 cm thick	30% of filamentous green algae > 2 cm long	Contact recreation & aesthetics	Biggs, 2000a
200	120	n/a	30% of filamentous green algae > 2 cm long	Protection of trout habitat	
50	50	n/a	n/a	Protection of benthic biodiversity	
50				Recreation and aesthetics	Nordin, 2001
100		n/a	n/a	Aquatic life	
100			40%	Recreation & aesthetics	Quinn, 1991
150					EPA, 2000
100-150				Coldwater fish & recreation	TetraTech, 2006
150-200				Warmwater fish & recreation	

Dissolved Oxygen: Algal activity leads to fluctuations in stream dissolved oxygen as photosynthesis and respiration occur. Typically, DO levels will be highest in the afternoon during peak photosynthesis and lowest near sunrise just prior to the restart of photosynthesis.

The Nevada Administrative Code (NAC) includes dissolved oxygen limits for many of Nevada's streams. For Class Waters, minimum DO limits vary from 5.0 mg/l for waters with trout, to 6.0 mg/l for waters without trout. Lower quality waters (Class D) have DO limits of 3.0 mg/l. Most other main stem streams have DO limits set at 5.0 mg/l regardless of fish species present. The NAC values are to be considered as instantaneous minimums.

EPA's Gold Book (EPA, 1986) provides somewhat different DO thresholds (Table 2). The high values for coldwater early life stages (9.5 and 8.0) may not be realistic for Nevada's waters. For example: for a stream at Elevation 5,000 feet and temperature of 21° C (typical summer temperature criteria in NAC), its DO saturation level is 7.4 mg/l. Without any algal photosynthesis activity, this water would not be able to meet the Gold Book Criteria during the peak afternoon temperatures.

Table 2. EPA Dissolved Oxygen Water Quality Criteria

Parameter	Description	Coldwater Criteria		Warmwater Criteria	
		Early Life Stages[1,2]	Other Life Stages	Early Life Stages[2]	Other Life Stages
30-day Mean	Average DO over a 30-day period	---	6.5	---	5.5
7-day Mean	Average DO over a 7-day period	9.5 (6.5)	---	6.0	---
7-day Mean Minimum	Average daily minimum DO for 7 days	---	5.0	---	4.0
1-day Minimum	Minimum DO for 1 day	8.0 (5.0)	4.0	5.0	3.0

[1]These are water column concentrations recommended to achieve the required intergravel DO concentrations (in parentheses) to support salmonid redds.
[2]Includes all embryonic and larval stages and all juvenile forms to 30 days following hatching.

Due to the diel fluctuations, the early morning DO is the most important value to measure as part of a monitoring scheme. Fortunately, DO monitoring has gotten much easier in recent years. The simplest approach for determining low DO levels for given site is to take readings near sunrise using a held-held DO monitor. A more intensive approach is the deployment of continuous DO monitoring sondes.

pH: Algal photosynthesis and respiration alter water pH with the uptake or release of carbon dioxide. As a result, pH levels can vary considerably over one day depending upon the buffering capacity (alkalinity) of the stream. Like DO, algal activity can lead to maximum pH levels during the afternoon with minimum pH levels prior to sunrise.

Most of the streams identified in the NAC includes pH limits of 6.5 – 9.0 for the protection of aquatic life based upon EPA guidance. These criteria are considered to represent instantaneous thresholds for pH measurements taken at any time during the data.
Due to the diel fluctuations, the early morning pH is the most important value to measure as part of a monitoring scheme. The simplest approach for determining low/high pH levels for given site is to take readings near sunrise and in the mid-afternoon using a hand-held pH monitor. A more intensive approach is the deployment of continuous pH monitoring sondes.

Suggested Nutrient Assessment Protocols for Nevada

This section presents a multi-tiered approach for assessing nutrient impairment status. In general, the assessment tiers are as follows. First, a Level I assessment can be performed to rather quickly identify possible problem areas. A Level I assessment is primarily qualitative in nature allowing for rapid assessments of numerous sites. If the Level I assessment indicates a possible nutrient problem, a Level II assessment is initiated which involves more quantitative measurements. The Level II assessment may be sufficient to determine impairment status, depending upon the extent of the data. If deemed necessary, a more rigorous Level III assessment can be pursued to better characterize the nutrient problem.

The extent of effort under each of these levels is not carved in stone. These levels are provided as general guidelines describing one possible way to assess nutrient impairment status. As always, in determining impairment status, professional judgment will be necessary on a case-by-case basis. NDEP must have flexibility in how these assessments can be undertaken, as dictated by the stream in question. It is fully expected that as experience is gained with these protocols, modifications will be made based upon lessons learned.

While the protocols were initially developed to assess 303(d) listed waters for nutrient impairment status, any of the three assessment tiers can be initiated for any water of interest, depending upon the needs of the investigator. In other words, a waterbody does not have to be exceeding its nutrient criteria or indicators for one to pursue any of these assessment tiers. As described in Nevada's Nutrient Criteria Strategy (NDEP, 2007), significant data are needed for a range of waters (from pristine to poor quality) throughout the state. Through the collection of data and analysis, NDEP will be able to test and refine its nutrient criteria strategy and these assessment protocols.

Level I Assessment

The Level I assessment relies primarily upon qualitative estimates of algal biomass as an indicator for possible next assessment steps. In addition to monitoring site location data, other information collected as part of the Level I assessment includes:

- ❑ Flow conditions (quantity, turbidity, etc.)
- ❑ Flow width and depth
- ❑ Canopy cover conditions
- ❑ Substrate type
- ❑ Indicate dominant species (rooted aquatic plants, attached algae)
- ❑ Percent cover of stream bottom with visible algae
- ❑ Percent cover of stream bottom with filamentous algae

Given the spatial and temporal variability of algal biomass, it is recommended that numerous locations be evaluated two or more times during the growing season. As water conditions can be highly variable, it may be necessary to visit the assessment site during two or more years. Further Level I guidance and field sheets are provided in Appendices B and C. Appendix D provides some charts useful in visually estimating percent cover.

If Level I investigations identify possible algae-related problems (percent cover >50%), then Level II investigations can be undertaken to further evaluate. The appropriateness of the >50% threshold needs to be tested over time. As shown in Table 1, some researchers have identified algae cover levels of 20 to 40% as affecting recreation and aquatic life uses. Regardless of the result of the Level I assessment, it may be desirous to perform a Level II assessment to better understand the system under study.

Level II Assessment

Under the Level II assessment, limited measurements of daily minimum/maximum DO and pH levels are taken for comparison to the water quality standards or indicators. In addition to the parameters collected in Level I, the Level II assessment consists of collecting the following: DO, DO saturation, pH and temperature near sunrise and in mid-afternoon (2 – 3 PM). Again, these data may be needed at numerous sites with measurements taken at least once every 2 weeks during the growing season.

Professional judgment will be needed to determine how much data are needed to make a nutrient impairment status determination. Some waters may require more data than others to reach a conclusion. As part of the assessment, it will be necessary to determine whether or not the DO and pH problems are due to algal activity and not other causes (low flow, acid mine drainage, etc.). Diel variations in DO and pH are good indicator of algal-driven DO and pH fluctuations, with maximum DO and pH in the mid-afternoon and the minimum levels near sunrise. Once DO and pH problems have been found to be caused by algal growth, a waterbody may be assumed to be nutrient impaired if more than 10% of days with DO or pH data exceed the standards or thresholds. It should be noted that algae can impact beneficial uses (aquatic life, recreation) even though no DO and pH problems are identified. More extensive investigations may be needed to further evaluate.

While a Level II assessment may be sufficient to determine nutrient impairment status, a Level III assessment may be desired to further characterize the problem and improve understanding of the nutrient/algal dynamics. In the assessment, it must be recognized that nutrient impairment problems can be greatly exacerbated by low flow and poor riparian shading conditions.

Level III Assessment

The Level III assessment can involve a much more detailed investigation including:

- Algal biomass monitoring
- Extensive DO, pH, temperature monitoring
- Water quality sampling for nutrient species
- Physical conditions (daily streamflow, substrate, shading)

Level III information may be useful in developing nutrient models as appropriate for setting TMDLs, assessing source control scenarios, determining nutrient criteria/indicators, etc. However given the detailed nature of the investigations, it is likely that Level III assessments will be limited to selected sites. As with the other levels, Level III monitoring may be needed at numerous sites over 2 or more years.

> **Algal biomass sampling:** While biomass data may not necessarily be needed to determine nutrient impairment status, biomass data will be useful as part of Nevada's overall nutrient criteria strategy and improved characterization of the algal dynamics. There are a few different algal monitoring methods that could be implemented for Level III assessments. Barbour et al. (1999) provides protocols for periphyton sampling in wadeable streams. While two sampling approaches are presented (multihabitat and single habitat sampling), the single habitat sampling approach is recommended when periphyton biomass is to be assessed. The recommended substrate/habitat combination is cobble obtained from riffles and runs. Examples of other approaches are provided by Biggs and Kilroy (1994) and New Mexico Environment Department (2004). NDEP may wish to test out the various protocols available before deciding on one consistent approach, or develop its own protocols as needed. Also, Region IX RTAG is planning on developing guidelines for algal monitoring for use in evaluating use support status and establishing nutrient criteria. These guidelines may prove useful for Nevada's nutrient criteria/assessment effort.
>
> **DO, pH, temperature monitoring:** Under the Level III assessment, it may be appropriate to collect hourly DO, pH, and temperature data using datalogging water quality sondes. Examples of sonde installations are provided by current Truckee River monitoring efforts and by recent Carson River efforts (Latham, 2006). This type of monitoring can be labor intensive requiring frequent site visits to ensure proper operation of sondes.
>
> **Water quality sampling for nutrient species:** Frequent (possibly weekly) sampling for a suite of nutrient species is needed to support a Level III investigation. Like biomass, DO, and pH, nutrient levels can significantly vary from day to day and from year to year.

If the sole purpose of the Level III assessment is to collect detailed DO, pH data to determine the nutrient impairment status, it may not be necessary to collect algal biomass and nutrient data at the detail suggested above. Lesser efforts may be appropriate and should be decided on a case-by-case basis. As described under the Level II assessment, a waterbody may be assumed to be nutrient impaired if more than 10% of the days with DO or pH data exceed the standards or thresholds. Biomass may also be used to determine impairment status. As suggested in Table 1, 150 to 200 mg/m^2 (chl-a) could initially be considered as a threshold above which streams would be considered impaired. The appropriateness of this threshold should be tested over time.

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Appendix A
Rapid Algal Biomass Monitoring Techniques

Appendix A – Rapid Algal Biomass Monitoring Techniques

Following is summary of some of the rapid-type assessment protocols.

"Stream Periphyton Monitoring Manual" (Biggs and Kilroy, 2000)

Method 1 - Percent Cover of Filamentous Algae

At 10 locations within 10 transects, a sampling quadrat (a square, rectangle, circle or other shape area used as a sample unit) is placed on the stream bottom. Using a viewing bucket, the percentage cover within the quadrat of filamentous algae which has filaments >3 cm long is estimated. The 100 values are averaged to determine the mean percent coverage by filamentous algae with filaments > 3 cm long

Method 2 – Percent Cover of All Algae

At 10 locations within 10 transects, a stone is picked up and % cover, thickness of mat or length of filaments, are estimated. The 100 values are averaged to determine mean percent coverage by diatoms with thicknesses greater than 0.3 mm, and mean percent coverage by filamentous algae with filaments > 2 cm long.

Both methods have been designed for assessing compliance with the Biggs' recommended guideline in Table 1.

"Rapid Bioassessment Protocols for Use in Wadeable Streams and River: Periphyton, Benthic Macroinvertebrates, and Fish" (Barbour, et al., 1999)

Qualitative Physical Characterization
The Rapid Bioassessment Protocols (RBP) include a qualitative physical characterization and component. The physical characterization field sheet includes one entry for an estimate of the percentage of study reach with aquatic vegetation.

Rapid-Periphyton Survey
At 3 locations within 3 transects, a viewing bucket (with a gridded clear acrylic sheet) is submerged so that the algae is visible through the clear bottom of the bucket. Diatom thickness[1] is estimated under each grid point; and filamentous algae length is estimated under each grid point.

While a rapid data collection approach is provided, algal biomass may not be collected in all instances where these protocols are implemented. Algal biomass is highly dynamic due to potential impacts from grazers, toxics, flow, etc.; therefore major emphasis has not been placed on quantifying algal biomass as part of the RBP.

[1] Thickness is assigned one of the following values: 0 – substrate rough with no visual evidence of microalgae; 0.5 – substrate slimy, but no visual accumulation of microalgae is evident; 1 – a thin layer of microalgae is visually evident; 2 – accumulation of microalgal layer from 0.5 – 1 mm thick is evident; 3 – accumulation of microalgal layer from 1 – 5 mm thick is evident; 4 – accumulation of microalgal layer from 5 mm – 20 mm thick is evident; 5 – accumulation of microalgal layer > 20 mm thick is evident

"New Mexico's Guidance for Nutrient Assessments of Streams" (2005)

New Mexico has established a multi-tiered approach for determining nutrient impairment status. In Level I, a number of factors (including water chemistry) are evaluated including a visual estimate of percent algal coverage. Coverages greater than 50% may indicate nutrient enrichment. Also, an estimate of periphyton thickness on coarse substrate is made with a thickness greater than 1 mm possibly indicating nutrient enrichment. If Level I suggests the possibility of nutrient impairment, a more rigorous Level II assessment (as outlined by Barbour, et al., 1999) is undertaken which includes algal sampling and laboratory analyses. The algal data are then compared to a nuisance algae level of 100 mg/m^2 (chl. A) to determine possible nutrient impairment.

There are also a number of examples where purely visual survey protocols are being implemented to characterize a variety of stream conditions, including algal growth. For instance, Missouri volunteer monitoring groups are using a visual survey as part of their program. Part of Missouri's visual survey includes an estimate of the following:

- Percent of stream bottom covered by visible algae
    - Percent of algae that is close-growing
    - Percent of algae that is filamentous (over 2 cm long)

Appendix B
Level I Assessment Guidance

Appendix B - Level I Assessment Guidance

Site Selection

The intent of these protocols is to monitor those sites with the highest potential for algae growth. With that in mind, the field crew should look for sites with limited shading, adequate substrate for algae growth (such as riffles). Since algae biomass can have great spatial variability, it is important to visit as many sites as reasonably possible (and as time allows) within the nutrient-listed waterbody reach and possibly upstream and downstream of the reach. As always, land ownership may greatly restrict the choice of accessible sites.

If the nutrient-listed waters in an area of interest are too numerous to survey in a season, surveys could focus on those streams with the higher OP, TP, DIN, TN levels occurring in the summer (not just during the runoff period).

Monitoring Timing/Frequency

The temporal variability of algae biomass suggests that the selected sites need to be visited several times in an attempt to capture the peak biomass period. It is likely that peak algae biomass levels will occur during periods of higher temperatures, lower flows, clear water and maximum sunlight – typically July through September. Therefore, these conditions should be targeted in the timing of the surveys. Areas with high algal cover (such as the EF Carson River between Highway 88 and Muller Lane) have been found to still have significant (50-75 % cover) algal levels even into November. Also, there can be variability from year to year so sites may need to be visited over multiple years.

As discussed above, Biggs (2000a) has shown that the time since the last scouring flow event can have a significant affect on the algal biomass on a given day. This needs to be kept in mind when planning the surveys. If it is known that high flows have recently occurred, it may not be appropriate to visit the site.

Gather Background Information

Prior to going out into the field, it is highly recommended that various background information be gathered. If sufficient information already exists that describes the eutrophication status of a given waterbody (or a portion), then actions other than a visual survey may be appropriate.

Background information may be valuable in selecting sites and the timing of the surveys. For example, NDEP and EPA have been performing physical habitat characterizations throughout Nevada. These surveys may provide some insight into algal conditions in the subject waters. Other sources of information may include BLM allotment assessments, fisheries assessments, etc. Personal communications with BLM, USFWS, NDOW, USFS field staff may also yield valuable background information.

Field Data Collection

It is recommended that at least 3 transects be established for each site to be monitored with survey stakes (or some other means) used to mark transect locations. Transects should be selected to be generally representative of the conditions within the riffle area. For each transect, the crew should estimate the average % algal cover (See Appendix C).

It is highly recommended that photographic documentation accompany any visual survey effort. This would include general photographs of the site along with photographs of the streambottom. However, it is important to establish transects or photo points that can be revisited during the algal growing season. For each transect, a series of photographs could be taken while walking across the stream and facing upstream/downstream depending upon the lighting and other conditions. As always, provide documentation of any photographs taken.

The above options should work well to capture changes over a given growing season. To monitor changes from year to year, it may be necessary to establish more permanent photo points. However, it may be appropriate to merely establish new photo points and/or transects each year at the same riffle/run.

Appendix C
Level I Assessment Field Form

Level I Nutrient Assessment Form

Nevada Division of Environmental Protection

Site Number		**Stream Name**	
Location Description			

Latitude/Northing		**Longitude/Easting**	
Datum		**Elevation (ft)**	

Survey by		**Date**		**Time**	

Weather Conditions	**Current**	
	Recent flushing flows?	

Stream Features	**Average width (ft)**		**Average depth (ft)**	
	Flow conditions (quantity, turbid?)		**Canopy Cover**	❑ Mostly open ❑ Partly open ❑ Mostly shaded
Riparian Vegetation	**Indicate the dominate type**	❑ Trees ❑ Willows	❑ Shrubs ❑ Grasses	
	Dominate species			
Substrate	**Indicate the dominate type(s)**	❑ Silt/Sand - <2mm (up to ladybug size) ❑ Gravel – 2 to 64 mm (ladybug to tennis ball) ❑ Cobble – 64 to 256 mm (tennis ball to basketball)	❑ Boulder - >256 mm (larger than basketball) ❑ Bedrock	
Aquatic Vegetation	**Indicate the dominate type(s)**	❑ Rooted aquatic plants	❑ Attached algae	
	Percent of stream bottom with suitable substrate for algae (typically gravel or larger)	❑ < 25% ❑ 25 to 50%	❑ 50 to 75% ❑ >75%	
	Percent of stream bottom covered by visible algae	❑ < 25% ❑ 25 to 50%	❑ 50 to 75% ❑ >75%	
	Percent of stream bottom covered by filamentous algae	❑ < 25% ❑ 25 to 50%	❑ 50 to 75% ❑ >75%	
Comments				

ATTACH Photos

Level I Nutrient Assessment
Photo Point Monitoring Sites – Description and Location
Nevada Division of Environmental Protection

Site Number		**Stream Name**			
Location Description					
Latitude			**Longitude**		
Datum			**Elevation (ft)**		
Survey by		**Date**		**Time**	

Map

Appendix D
Charts for Estimating Percentage Algal Coverage

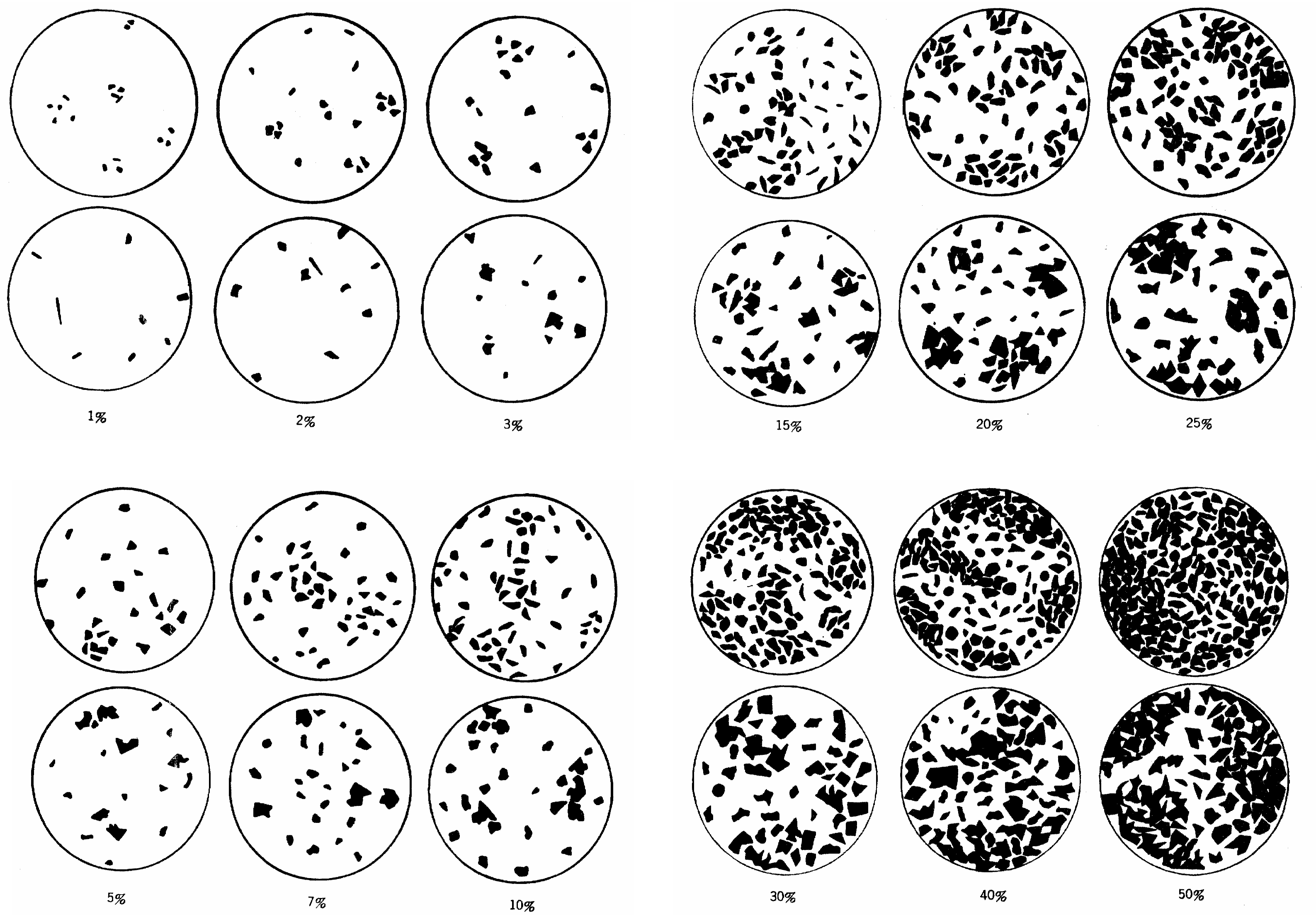

Figure D-1. Charts for Estimating Percentage Algae Coverage (Taken from R.D. Terry and G.V. Chilingar for Journal of Sedimentary Petrology (v. 25, pp. 229-234, 1955.